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THE

CANALIZATION OF RIVERS

AND THE DIFFERENT SYSTEMS OF MOVABLE WEIRS

REPORT

BY

Leveson Francis VERNON-HARCOURT, M. A.
M. Inst. C. E.

PARIS
IMPRIMERIE GÉNÉRALE LAHURE
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CANALIZATION OF RIVERS

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The advantages of converting rivers into still-water navigations, by the erection of locks and weirs at suitable places, for extending the facilities of navigation into the interior of a country, are fully recognized at the present time. The only points upon which differences of opinion might arise are, as to the best methods for effecting the canalization; the extent to which canalization should be carried; the minimum depth that should be obtained; the amount of expenditure that might reasonably be incurred; and whether this expenditure should be borne by the State, or by private companies. Some of these questions do not admit of any general settlement; for the capabilities of any river for the extension of canalization depend upon the natural physical conditions of the special river; and the expenditure on the works, besides depending upon these natural conditions, must be also regulated by the prospects of increased trade which an improved waterway would offer. The improvement of the waterways up to such places as Paris, Lyons, Brussels, Liége, Berlin, Mannheim, and Frankfort, might justify a considerable expenditure; whereas similar improvements up to smaller centres of trade could only be undertaken under specially favourable conditions. Gently-flowing rivers are more suitable for canalization than torrential rivers; for their smaller fall admits of their conversion into still-water navigations with fewer locks and weirs; and their water-levels are much less variable, as their floods rise considerably less, and they are less exposed to a scarcity of water in times of draught. For similar reasons, the lower portions of rivers are generally better adapted by nature for canalization than the portions nearer their sources.

Depth of water. — The minimum depth of water in the navigable channel of a river, and the dimensions of the locks, determine the size of the craft that can navigate the river; and whereas an augmentation of depth, by retaining a higher water-level, or by dredging, adds materially to the cost of canalization works, it also allows of a considerable increase in the tonnage of the vessels. Each river is, in a certain sense, a separate waterway; but as most of the larger rivers of Europe are connected by canals traversing the boundaries of their basins, uniformity of depth is to some extent desirable, especially in the upper portions of the rivers, to admit of an interchange of traffic between the various navigations, and with adjacent canals. It is easier, however, to secure a good depth in the lower portions of rivers, where the river is large and its fall slight, than in the higher portions above the confluence of some of the tributaries, and where the fall is greater. Consequently, a better depth is commonly obtained in the lower sections of rivers than higher up. For instance, the available navigable depth of the Seine up to Paris was made $5\frac{1}{4}$ feet (1^m,6) by works completed in 1866, and is being increased to $10\frac{1}{2}$ feet (3^m,2) : it was raised to $5\frac{1}{4}$ feet (1^m,6) in the Upper Seine, between Paris and Montereau, by works commenced in 1860, and was increased to $6\frac{1}{2}$ feet (2^m) by supplemental works in 1878-81. Moreover, the depth of $10\frac{1}{2}$ feet (3^m,2) between Saint-Aubin and Paris, a distance of 135 miles (217 kilomètres), is secured by nine locks and weirs; whereas the depth of $6\frac{1}{2}$ feet (2^m) between Paris and Montereau, a distance of 52 miles (83 kilomètres), has only been attained by thirteen locks and weirs. Again on the Rhine, where the navigation is open, the navigable depth, at the low stage of the river, is 7 feet $10\frac{1}{2}$ inches (2^m,4) up to Cologne; 7 feet $2\frac{1}{2}$ inches (2^m,2) from Cologne up to some distance above Coblenz; and $6\frac{1}{2}$ feet (2^m) up to Mannheim, with the exception of a shallow portion between Bingen and Saint-Goar, where the available depth falls to 5 feet (1^m,5) in times of drought. The depth has been improved in places, especially between Mainz and Bingen, by means of training works, regulating and narrowing the channel; but probably the depth over the rocky shoals below Bingen could be best augmented, so as to conform with the channel above and below, by the erection of a lock and weir at this part of the river, owing to the greater fall of the river bed in this section. These works, besides affording a much-needed increase in depth, would facilitate the up-stream traffic, by diminishing the rate of the current through the rocky passes with the attending risks, and would only slightly delay the down-stream traffic.

Training works proved of little advantage for improving the depth of the river Main; whereas a minimum depth of $6\frac{1}{2}$ feet (2^m) has been obtained from its outlet, opposite Mainz, up to Frankfort, by the erection of five locks and weirs within a distance of 21 miles (34 kilomètres) from its mouth. The increase in depth from 3 feet (0^m,90) to $6\frac{1}{2}$ feet (2^m), has

resulted in such an enormous development of traffic, that is was determined last February, within three years since the completion of the works, to augment the minimum depth to 8 feet 2 ½ inches (2m,50), for which provision has been made in the sills of the locks when constructed. This proposed increase in depth, if unaccompanied by corresponding improvements in the Rhine, especially between Bingen and Saint Goar, will produce the anomalous result of affording a better navigable depth along the Main, from Frankfort down to Mainz, than along the Rhine from Mainz down to Cologne. Probably, however, the much smaller basin of the Main, as compared with the Rhine, renders the Main more subject to drought, and therefore liable to remain at its low-water stage for a longer period.

It is evident from the traffic along the Rhine up to Mannheim, along the Main up to Frankfort, along the Seine, and along the canals leading from the North Sea ports and Belgian coal-fields to Paris, that a minimum depth of 6 ½ feet (2m) can accommodate a very large trade. This is the depth which has been adopted as the standard for the main lines of the French waterways, and is undoubtedly the minimum which should be aimed at for waterways of any importance, though occasional falls at places between that limit, as on the Rhine below Bingen, do not present insuperable obstacles to the development of trade. Accordingly, no river can be regarded as a main waterway where this limit cannot generally be reached, at a reasonable cost, owing to unfavourable physical conditions. Those navigations, indeed, have been the most successful, which have been able to respond to a growing traffic by affording an increased depth. The Aire and Calder Navigation in England is an instance where a waterway, by successive extensions of depth, from 3 ½ feet (1m,07) to 5 feet (1m,50), from 5 feet (1m,50) to 7 feet (2m,17), and then up to 9 feet (2m,75), has remained a flourishing enterprise in the face of keen competition with railways. The Welland and Saint Lawrence canals have similarly undergone successive enlargements, so that their present available depth is 14 feet (4m,27). On rivers leading up to important centres of trade, the greatest navigable depth should be obtained, consistent with an outlay which the increase of traffic may be expected to repay, irrespective of the depth of the river above, or of connecting waterways.

Dimensions of locks. — The size of the locks on a river are of the same importance as the depth, for it determines the dimensions of the craft that can pass along the river. The depth over the sills must be equivalent to the minimum depth along the navigation channel elsewhere; and it is advantageous, when there is any prospect of a future improvement of the waterway, to place the sills lower than the available depth of the river in constructing the locks, so as to enable a deepening of the river to be subsequently effected without the troublesome operation of altering the locks. This was the course which was fortunataly adopted in canalizing the Main, the sills of the locks having been made 1 fect 7 ½ inches (0m,50) lower

than the navigable depth, which renders the proposed deepening a much simpler work. The width of a lock must afford a certain margin beyond the width of the largest barge navigating the waterway, to prevent the vessels fitting so closely as to act like a piston in entering or leaving the lock, and thus being delayed in their progress. The regulation dimensions on the principal waterways in France are a depth of 6 $\frac{1}{2}$ feet (2^{m}), a length of 126 $\frac{2}{3}$ feet (38^{m}), and a width of 17 feet (5^{m},20); but, considerably larger locks are provided on the Lower Seine. The locks on the Aire and Calder navigation, the most flourishing inland waterway in England, has locks 215 feet (65^{m},80) long, 22 feet (6^{m},70) wide, and 9 feet (2^{m},75) deep and the locks on the Weaver navigation in Cheshire are being enlarged to 220 feet (67^{m}) by 42 $\frac{1}{2}$ feet (13^{m}) by 15 feet (4^{m},60). The dimensions of locks in the lower portions of rivers are less restricted than on canals and the upper parts of rivers; for, giving direct access for the sea to important centres of trade, they need not be limited to dimensions which form the pratical limits of the inner system of waterways. Moreover, the larger and more regular discharge of the lower portions of rivers renders them more independant of the loss of water by lockage. Accordingly, the large locks on the Lower Seine are 462 feet (140^{m}) long, and 55 $\frac{3}{4}$ feet (17^{m}) wide, with a depth over their sills of 10 $\frac{1}{2}$ feet (3^{m},20), to conform with the increased navigable depth of the river; and at Suresnes and Bougival, the lengths have been carried to 526 feet (160^{m}) and 722 feet (220^{m}) respectively. On the Main, the locks have been made 279 feet (85^{m}) long between the gates, and 34 $\frac{1}{2}$ feet (10^{m},50) wide, and have their sills placed 8 feet 2 $\frac{1}{2}$ inches (2^{m},50) below the waterlevel; and it has been decided to lengthen the locks to 1165 feet (355^{m}), by a third pair of gates in the lock channel, to enable a tug with its train of barges to be locked at one time. Whilst therefore the dimensions of the lock-chambers must be at least sufficient to admit the largest vessels navigating the adjacent waterways, any extension beyond these limits must be determined by the position of the waterway, and the nature and extent of its traffic; the largest locks being required by those waterways combining a good depth with direct access to the sea, and consequently best suited for a large navigation.

It is expedient to reduce the time occupied in passing through locks by forming large culverts in the side walls, whereby the lock-chamber can be rapidly filled and emptied, and by introducing hydraulic machinery for opening and closing thelock-gates, for raising and lowering the sluice-gates, and for working capstans to haul the vessels in and out, whenever the amount of traffic warrants such an expenditure. Next to an ample depth, quick transit through the locks is of importance in developing traffic; for the loss of time in the passage is equivalent to an elongation of the route, which both adds to the cost of conveyance, and in the case of competition with other waterways or railways is very prejudicial. Lifts, which save so

much time on canals when substituted for a flight of locks, are not suitable for replacing a single lock in the usually moderate difference of level between two adjacent reaches of a canalized river.

Scarcity of water is not generally experienced on the larger river navigations, and therefore provisions for economising water in lockage are not so important as on canals; but locks of different sizes side by side, and an intermediate pair of gates in the larger locks, enable the expenditure of water to be reduced, provide for a large traffic of various sized vessels, and expedite the passage. By widening out the lock-chamber inside the gates, larger accommadation is provided without increasing the cost of the entrances, the most costly portions of the lock. This expedient is common in America, and has been adopted on the Lower Seine; but its adoption must depend on the nature of the traffic and the supply of water; for if there are not generally sufficient vessels ready to fill the lock, a waste of water ensues.

Tidal extension and canalization. — In recent years, a desire has been exhibited to extend communication with the sea, and convert inland towns into seaports. Thus schemes have been proposed for making Paris, Brussells and Manchester seaports. It is unquestionable that enormous advantages have been gained by deepening the rivers leading up to Rouen, Rotterdam, Newcastle, Glasgow, and Middlesborough, and thus making them in reality seaports, which previously they were only in name. The tide, however, always came up to those towns; and the only means of making them accessible to large vessels was by deepening the channel of the river, leading to the sea, by dredging or training walls. The channels have been made much deeper, and the tidal influx has been facilitated; but the tidal limit has not been materially modified. The advantages of direct communication with the sea have been rendered so apparent by the great developement of trade resulting from these works, that towns higher up rivers have naturally desired to obtain similar facilities for traffic. The scheme, however, for extending the tidal Seine nearly to Paris, and the plan once proposed for leading the tidal Mersey up to Manchester, differ totally from the tidal river improvement works referred to above. Such enterprises constitute gigantic works, resembling the ship-canal works of Suez and Panama, which have so greatly added to the renown of French engineers. An expenditure, however, which may be reasonable enough for opening out a route of worldwide utility, can hardly be justified for affording advantages, however great, to a single town. The scheme of cutting a channel for the tidal Mersey up to Manchester has been abandoned; and the works in progress will afford similar advantages, by means of canalization, at a much more reasonable cost. If Paris should at a future time require a better waterway than the 10 $\frac{1}{2}$ feet ($3^{m},2$) depth of channel can provide, it would be much better to extend the system of canalization for attaining a greater navigable depth, than to attempt to carry out works

for bringing the tidal Seine nearly up to Paris, which would be so costly, and would introduce such important modifications in the regime of the Seine valley.

The limit of the tidal flow and the rise inland of the river bed indicate where canalization may naturally commence; and canalization affords, generally, the best means of improving a waterway beyond the tidal limit.

The different Systems of Movable Weirs.

Weirs are essential concomitants of locks in canalizing a river, for they serve to raise the water-level, and thus improve the depth; and, by retaining the water in times of drought, they prevent the lowering of the water so common in dry weather with rivers left in their natural conditions. It is hardly necessary in France to lay stress upon the fact that the natural flow of a canalized river should be impeded as little as possible in flood-time, in order to maintain as for as practicable the original condition of the valley : and that therefore weirs that can be removed from the river during the period of floods should be adopted. These movable weirs have the inestimable advantage of maintaining the water-level of a river just as well as a solid weir in summer time, of regulating the efflux according to circumstances, and of leaving the river unobstructed in flood-time. French engineers were the first to recognize and act on this principle; and to Poirée, Chanoine, and Desfontaines are due the principal types of movable weirs, which their able successors have perfected (Plate I, figs. 1, 5, and 7).

The earliest form of movable weir consisted of the stanches placed across rivers, closed by paddles or needles, for producing temporary canalization, and flashes, when released, to carry the vessels over the shallows below. Weirs of this primitive type were introduced on English rivers as well as in France, and still exist on the Thames above Oxford. When, however, a regular system of canalization was adopted on French rivers, more elaborate arranguments were introduced. A variety of systems have been tried, such as the Bear Trap at Laneuville on the upper Marne, taken from an American form of weir; the double Shutter weir of Mr. Thénard on the river Isle, subsequently adopted on a large scale for Indian irrigation works, and provided with the important improvenent of an hydraulic brake by Mr. Fouracres[1]; the Hydraulic Shutter weir of Mr. Girard at Brûlée Island on the river Yonne, where the necessary force for raising the shutter against the stream is obtained by the fall of water from the upper pool; and the Pontoon weir of Mr. Krantz, experimented on at Port-Villez, on the Lower Seine. There are, however, only three systems in

1. « Minutes of Proccedings. C. E. » vol. LX, p. 43, plat. 5.

general use at present on canalized rivers, namely, the Frame weir, the Shutter weir, and the Drum weir[1] (Plate I, figs. 1, 5, and 7.)

Frame weir. — The frame weir consists of a series of movable frames, placed at intervals across the river, and supporting a barrier retaining the water, which is formed of needles, panels, or rolling-up curtains (Plate I, figs. 1, to 4). After the removal of the barrier as a preparation for floods, the frames can be withdrawn, for the waterway, either by being lowered on to the apron of the weir to which they are hinged, of which type the finest examples exist at Suresnes and Port-Villez (Plate 1, figs, 2 et 3); or they can be raised entirely out of the river when suspended from overhead girders, as at Poses and Port-Mort. (Plate I, fig. 4.) The first arrangement of the frames has the disadvantage of leaving the frames at the bottom of the weir during the whole winter, liable to be covered with the debris brought down by floods, and to be injured by then stria in raising them to reinstate the weir. This objection is obviated by the second arrangement, comprising an overhead bridge with suspended frames; but this construction necessitates a strong bridge, right across the river, spanning the openings between the piers of the weir, and raised on high piers at the navigable passes, so as to leave the requisite headway for vessels, under the girders, above the highest navigable water-level. (Plate I, fig. 4.) This arrangement might be of great importance on rapid rivers like the Rhone, where the frames when lowered, might be buried under large masses of shingle brought down by the river, for which the scheme was originally devised; but it appears a costly expedient for the gently-flowing Lower Seine, where the frames at all the weirs have been lowered on to the river bed in winter for many years, and raised without much inconvenience. Undoubtedly, the lifting up of the frames, and thus removing all the delicate parts of the weir out of the river in flood-time, is the most perfect system; but engineers must be guided in their designs by relative expenses; and except for paramount considerations, a considerably greater cost may render the most perfect theoretical system inexpedient. The original plan of closing the frame weir by needles (plate I, fig. 1) is still in use on the Seine, the Marne, the Meuse, and other rivers, and has been adopted for the recently erected weirs on the river Main : it possesses the merit of simplicity; and by aid of the Kummer arrangement, the needles can be rapidly released. The objections which may be urged against the employment of needles are, the chance of the submergence of the footbridge on the frames by a sudden flood before the needles can be released, the leakage which occurs between the needles, and the liability of the needles to wear, loss and breakage. The fear of submergence of the footbridge, however, can be removed, either by the addition of a long overfall weir, as adopted on the Meuse

1. *Ibid*,, pp. 30 to 38, and plates, 2, 3 and 4.

below Namur, or by placing another form of weir across a portion of the river alongside the needle weir, such for instance as the shutter weir put across one of the shallow passes in the Meuse weirs above Namur, or the drum weir closing the timber pass at the side of the Main weirs. Leakage between the needles has been prevented by placing a canvas curtain against the upstream side, or other temporary expedients; and, moreover, except in times of severe drought, the leakage does not usually exceed the necessary outflow of the river. The needles also, though somewhat readily worn and injured, are readily renewed, owing to their simple form.

When the height of the weir exceeds about 11 feet (3^{m},35), needles cease to be suitable for closing the frame weir, as the requisite increase in their size would render them difficult to handle; and Mr. Boulé's panels, or Mr. Caméré's hinged curtains, provide convenient substitutes for forming the movable barrier. The hinged curtain adopted for Port-Villez, Poses and Port-Mort (pl. I, figs. 3 and 4) has the advantage of enabling the discharge to be perfectly regulated by rolling up the curtain more or less; but as the curtain is raised from the bottom a great scour occurs along the apron. The panel system, adopted at the Mulatière weir, across the Rhone near Lyons, and at several weirs across the river Moskva, and on trial at Suresnes (pl. I, fig. 2) side by side with the hinged curtain, does not allow of quite such an exact regulation of the discharge as the curtain, for there are only four panels for closing each opening between a pair of frames at Suresnes. On the other hand, however, the discharge flows over the panels, and therefore does not cause a scour along the bottom. It is also much simpler in construction than the hinged curtain, and less liable to get out of repair; and the panels will probably last longer. Either arrangement, however, enables the height of the frame weir to be considerably extended; and whereas the limit for frames lowered on to the bed of the river has probably been reached at Suresnes and Port-Villez, the height of a weir with suspended frames might be easily increased, if necessary, beyond the present limit of about 17 feet (5^{m},20). The instances, however, where weirs might be required to retain a greater head of water than 13 feet (4^{m}) would be very rare, as in canalizing a river it is not advisable to introduce great alterations of the water-level.

Shutter weir. — In 1852, Mr. Chanoine introduced a modified system of shutter weir, on the Upper Seine, suitable for closing a navigable pass, which has formed the model for subsequent weirs of the same type in France, and has been adopted in Belgium and America. This type of weir, of which one of the largest examples has been erected across the navigable pass at Port-à-l'Anglais weir on the Seine just above Paris (plate I, fig. 5), possesses the advantages of forming a more watertight barrier than needles, of being adapted for regulating the water-level by the tilting of the shutters, or by the aid of automatic butterfly valves, and of being rapidly lowered by means of a tripping bar on the arrival of a flood. The

shutters, trestles, and prop, are, however, far more complicated than the needles of the frame weir; and, falling on to the apron in opening the weir, are much more liable to injury. Moreover the shutter weir, when furnished with the important adjunct of a footbridge on hinged frames, like those of a needle weir, which greatly facilitates its working, is considerably more costly than the needle weir. It was also found, in the shutter weirs on the Meuse above Namur, that the raising of the shutters caused abrupt variations in the water-level, and that the last shutters were difficult to raise, so that needle weirs have been substituted for shutter weirs in the navigable passes of these weirs. In making alterations, moreover, in the Upper Seine weirs, some of the shutter weirs were replaced by needle weirs, indicating, like on the Meuse, a tendency to revert to the simpler and older type of weir which was exclusively adopted on the Lower Seine, and the Meuse below Namur, which serves to close the navigable passes on the Marne, and has of late years been selected for the weirs on the Main. The shutter weir, accordingly, seems likely in the future to give place to the frame weir, owing to its greater cost of construction its liability to injury, and the difficulty of setting right any derangement of the prop without the aid of a diver.

Another form of shutter weir, designed by Mr. Wiswall, engineer to the Bridgewater Canal, has been erected across the Irwell, at Manchester [1]. It is called a tilting weir; and the shutters, revolving at a nearly central horizontal axis, are moved by chains rolling round windlasses on each bank. (Plate I, fig. 6.) The shutters were designed to tilt as soon as the river had risen a certain height above them, so as to increase the discharge automatically; but this adjustment proved rather irregular in practice, and it was found better to regulate their position entirely by the chains. This form of weir is not suitable for navigable passes, as the frames, on which the axes of the shutters rest, stand permanently fixed on the apron; and therefore the shutters assure a horizontal position in midstream when the weir is open, and together with the frames occupy rather more than one fifth of the total sectional area of the waterway. This form of shutter weir, accordingly, though very readily opened, closed and adjusted, is a movable weir in only a limited sense; and, with its chains for each shutter, would not be suitable for very wide openings.

Drum weir. — Till recently, the drum weir has been restricted to the Marne, where it was introduced by Mr. Desfontaines for closing the shallow passes of the weirs. Its striking feature is the complete control obtained over the weir by means of the see-saw arrangement of sluice gates in the piers, regulating the action of the stream upon the lower paddle revolving in the drum, enabling the upper paddle to be raised against the stream or lowered to any angle. The depth, however, required for the fundations

1. « The Engineer », Sept. 1, 1882.

for the drum below the sill of the weir, rendered it costly, and apparently unsuitable for navigable passes. Nevertheless, its adoption for closing the timber passes on the Main [1], and also at a deep pass across the Spree at Charlottenburg [2] (Plate I, fig. 7), has shown that its costly fundations do not preclude its employment for navigable passes; and wherever perfect control, and rapid opening and closing of a weir are of more importance than economy in construction, it is a form of weir which may hereafter be more extensively introduced. It might also serve very usefully, in conjunction with a frame weir, as a regulator of the discharge over the weir, owing to the precision with which the position of the upper paddle can be adjusted. The drum weir forms a very perfect hydraulic contrivance, being actuated by the head of water above, and needing no foot-bridge to facilitate its working; and its cost of maintenance is small.

Stoney's sluices on Free Rollers. — Before passing from the subject of movable weirs, another form of weir should be alluded to, which, though approximating more to drawdoor weirs, such as the weir at Teddington on the Thames [3] and other English weirs, than to movable weirs, possesses some of the main advantages of movable weirs, has much greater ease of motion than other draw down weirs, and might perhaps, with certain modifications, be made to serve all the requirements of movable weirs. This weir consists of large sluice-gates sliding against free rollers hung on chains, and moving with the gates, at each side, whereby the friction is so much reduced that the sluice-gates can be readily raised when there is the pressure of a considerable head of water against their upper faces [4]. This system of sluices was invented some years ago by Mr. F. G. M. Stoney; and the largest gates on this principle have been erected at Belleek and Ballinasloe, in Ireland, across the rivers Erne and Suck, to control the drainage works connected with these rivers, which I had the opportunity of visiting last November,

The Belleek sluices consist of four openings, 29 feet 2 inches (8^m,90) wide, closed by gates, 31 feet (9^m,45) wide, 14 $\frac{1}{2}$ feet (4^m,42) high, and weighing 13 tons each, which can be easily lifted separately by one man against a water pressure of 80 to 100 tons, the height to which they can be raised above the sill being 9 feet (2^m,75). A small turbine, on the right bank, can lift all the sluice-gates together. A light girder bridge, resting on the piers between the sluices, carries the gearing for raising the gates, and gives access across the river. These sluices have enabled a rocky dam in the river to be removed; and whilst holding up the water-level in dry weather in Lough Erne and the adjacent Ulster Canal,

1. « Zeitschrift für Bauwesen », 1888, p. 27 and plate XVII; and « Minutes of Proceedings Inst, C. E. » vol. XCVI, pp. 191, to 193.
2. « Zeitschrift für Bauwesen », 1886, p. 338, and plates XXXI and XXXII.
3. « Minutes of Proccedings Inst. C. C. », vol. LX, p. 25, and plate I, figs. 11 to 13.
4. Ibid., p. 88, plate 6.

for the sake of the navigation, have effected a reduction in the rise of the floods from 10 feet (3^{m}) to 3 feet (0^{m},90), by lifting the gates on the approach of a flood. They were erected in 1883. The Ballinasloe sluices have four openings of 25 feet (7^{m},60) span each, closed by gates sliding on free rollers, like at Belleck, 8 feet 9 inches (2^{m},67) high, which can be raised 7 feet (2^{m},13) above the sill. The sluice-gates are placed against the upper side of an arched stone bridge, crossing the river Suck in four spans at Ballinasloe, and, being counterbalanced, can be raised more easily and rapidly than the Belleek sluice-gates, which have no counterpoise.

This system is obviously specially well adapted for sluice-gates; and sluice-gates on this principle are being erected on the Manchester Ship-Canal[1], to regulate the efflux of the rivers Mersey and Weaver into the Mersey estuary, as both these rivers are intercepted by the canal. If, however, two such gates were suspended from the two arms of a swing-bridge revolving on a central pier, they would serve to close navigable passes; and their employment for lock-gates and sluices combined has been proposed by their inventor.

Movable Weirs across Tidal Rivers. — Last autumn, I was consulted as to the means by which the unsatisfactory condition of the river Thames, at low tide, between Richmond and Teddington might be remedied. By the removal of the old bridges across the Thames at London with their wide piers and small openings, and by dredging, the low-water level of the river has been gradually lowered; whilst the summer discharge of the river over Teddington weir, the limit of the tidal flow, has been increasingly encroached upon by the Water Companies, so that now about one third of the total summer flow in dry seasons in abstracted before reaching the weir. Large portions of the river bed, accordingly, are laid bare at low tide between Richmond and Teddington, which are covered with slime deposited by the tide during slack water in summer time. Boating is now only possible for a short period near high tide; and the unsanitary condition of the exposed mud-banks has caused a great depreciation in the value of residential property along this part of the river. The difficulty consisted in devising a scheme which, whilst improving the state of this part of the river at low water, should not undully restrict the tidal flow in a river which possesses the vast port of London lower down. A fixed weir at half-tide level, near Richmond, whilst restoring the river to somewhat its previous condition, and covering the mud-banks with water, would check the flood-tide, and raise the water-level above in flood-time. To solve the problem satisfactorily, I came to the conclusion that it would be necessary to erect a movable weir a short distance below Richmond, which,

1. The shuice-gates already erected are 30 feet (9^{m},2) span, 16 feet (4^{m},2) deep, and weigh 24 tons, fully counterblaanced: and one man can raise a gate 4 feet (1^{m},22) to 4,$\frac{1}{2}$ feet (1^{m},37) per minute.

when closed, should retain the water at about half-tide level, but which should be entirely open and removed from the waterway when the river was above that level, either owing to the tidal rise, or the passing down of flood-waters. Such a weir would have to be opened as soon as the river rose above half-tide level, and closed again as soon as it fell below that level. Accordingly, except in floo time, the weir would have to opened and closed at every tide, a condition which could not be fulfilled by any form of frame, or shutter weir. The only systems of weirs which, as far as I am aware, would at all meet the requirements of the case, are the drum weir, and a modified form of sluice-gates on free rollers, hung from a swing-bridge across part of the river. As the obstruction to the landscape, caused by a high bridge and the gates when lifted, might be deemed objectionable, the preference ought probably be given to the drum weir, which, placed in a tidal river, would occupy quite a novel position.

General considerations relating to Canalization of Rivers.

Considerable interest attaches to the question of the extent to which the canalization of rivers should be carried, and the manner in which the cost of the works should be defrayed. It has been already pointed out that canalization becomes more difficult in going higher up rivers, for the inclination of the river bed becomes steeper, and therefore more frequent locks and weirs are required; the volume of water becomes smaller, and therefore the natural depth of the river is smaller; and the flow is less regular. Moreover, the higher portions of the valleys are steeper and less fertile, and consequently generally less populous. Accordingly, the canalizatiou of rivers is inexpedient beyond a certain point, as the works are proportionately increased, and the prospect of traffic becomes less, unless a connection with other waterways has to be established. Moreover, in such cases, sometimes a lateral canal is preferable to a canalized river, especially when the river is torrential, as for instance in the Upper Marne valley, where the traffic follows the canal.

It is clear that private Companies should not undertake works that do not afford a reasonable prospect of a fair return on the outlay. With a State, the case is somewhat different; for a connecting link, or an improved waterway may be unremunerative in itself, but, by opening out communications and developing traffic elsewhere, it may prove an indirect gain to the State. Though, therefore, it is very questionable whether the State should treat waterways like roads, and provide or improve them at the expense of the community at large, and throw them open free of toll, there is no doubt that the State is better qualified than private companies to establish a comprehensive system of waterways. Indirect profits, beyond the limits of any special waterway, are no benefit to a

private company owning the waterway, but may be remunerative to the State, which profits by the general prosperity of the community at large. State ownership of waterways on the continent, also, is not open to the objection raised against it in England of entering, with public money, into competition with private railway companies, since the State is the cheef owner of the railways as well. A general State ownership, moreover, of the waterways of a country enables, to a certain extent, the burden of useful, but unremunerative works of improvement to be borne by the revenues of the very frequented waterways, and facilitates the esta blishment of a uniform system for the main waterways, abolishing the differences in depth and in the dimensions of locks so fatal to the development of through traffic. The State, however, dealing with the general public funds, appears somewhat bound to afford equal advantages to the whole country, and therefore is liable to be pressed to grant to all the districts the facilities of transit easily accorded to a few favourably situated ones, and thus be led to embark upon works which cannot be directly or indirectly remunerative. A way of obviating this would be for the district proposing the construction of a new waterway, or the improvement of an existing one, to be obliged to give a contribution or submit to a rate, so as to bear a definite share of the expense in the event of the work being approved, the State maintaining the control and giving a grant in aid. Some such an arrangement might hinder unprofitable undertakings, as the district would not consent to subscribe unless the benefit was fairly assured.

A glance at the traffic returns of the inland waterways of France shows that the principal traffic is restricted to the Seine, and to the waterways connecting the North Sea ports and the Belgian coalfields with Paris, whilst the only other waterways which possess a fair traffic are the Marne lateral Canal, the Marne-Rhine Canal, the Loire lateral Canal, and the Berry and Central canals in connection with it, all leading from the interior towards Paris. On three fourths of the total lenght of navigable rivers in France, or 3519 miles (5663 kilomètres), the traffic is less than 100 000 tons in the year; on only 26 miles (42 kil.) is there a traffic of 2 000 000 tons a year; on 135 miles (217 kil.), a traffic of between 1 and 2 million tons; and on 203 miles (327 kil.), a traffic of half a million to 1 million tons in the year. These figures show how small a traffic has resulted from the outlay on a considerable portion of the river navigations, in spite of the absence of tolls, and that if such an extension of canalization is beneficial, it can only be carried out by the State; for the traffic on three fourths of the river navigations could offer no inducements to private enterprise.

Conclusions.

The conclusions that may be drawn from the above considérations are as follows:

1. That 6 ½ feet (2^{m}) is the minimum depth that can be admitted for the main lines of inland waterways of a country; and that with this depth, under favourable conditions, a very large traffic can be accommodated.

2. That for the lower portions of rivers with good access to the sea, a greater depth than 6 ½ feet (2^{m}) is of considerable advantage, as the facilities for traffic and large cargoes increase rapidly with the available depth.

3. That the size of locks must be determined by the nature of the traffic; and that in constructing locks on a new navigation, it is advisable, where there is any prospect of increasing the navigable depth at a future time, to place the sills lower than the depth at first provided, in order that the locks may be available, without alteration, for an improved navigation, thus saving the inconvenience, delay, and cost, of lowering the sills.

4. That larger locks are expedient in the lower portions of rivers, intervening between the sea and large centres of trade, where the traffic is generally the greatest; and that intermediate gates, or smaller adjacent locks, should be provided to suit various sizes of craft, and to save water and more specially time in locking.

5. That at locks where the traffic is large, ample culverts along the side walls, and hydraulic machinery should be introduced for saving time in locking, thus hastening the transit, and increasing the accommodation of the locks.

6. That canalization is much more efficient in increasing the navigable depth of a river than training works, except when the fall of the bed is slight, and the deficiency in depth is due to considerable variations in the width of the river.

7. That beyond the natural tidal limit, canalization is preferable to an extension of the tidal channel far inland by large excavations, as being much cheaper, and equally efficient with adequate works, such as those in course of construction on the Manchester Ship-canal, and interfering much less with the natural condition of the river valley.

8. That frame weirs and drum weirs are the most suitable forms of movable weirs.

9. That by the substitution of sliding panels, or hinged curtains for needles, the frame weir can be extended considerably beyond its previous limit of height of about 11 feet (3^{m},35); and that up to about 21 feet in height, attained by the frames at Suresnes weir, the frame hinged to the apron, and lowered on to the river bed, is the cheapest form, and can be

managed in gently-flowing rivers without inconvenience. That for rapid rivers, and greater heights, the costlier but more perfect form of frame weir, with frames suspended from an overhead bridge, would be the most suitable.

10. That the drum weir is the most perfectly adjustable form of movable weir; and that though its costly foundations might have appeared to limit its employment to serving as a regulator of discharge in conjunction with a frame weir, yet it has already been adopted for a navigable pass; and that its great facility of working, without the aid of a footbridge, will probably lead to its more general adoption in special cases. That the drum weir appears applicable to the novel condition of partially retaining the water in the shallow upper portion of a tidal river near low tide, whilst leaving the waterway perfectly open for the flow and ebb when the water is above the requisite minimum level.

11. That the improvement of waterways throughout a country can be only comprehensively carried out under State control.

12. That waterways cannot be considered a universal public necessity like roads; and that therefore considerations of direct or indirect returns should influence the improvement or extension of the canalization of rivers; and that the districts interested in the works should share the cost with the State.

13. That the statistics of traffic on canalized rivers in France indicate that a large proportion of these navigations can yield little or no profit even indirectly, and can only be useful in keeping down rates of conveyance, and of value in the districts through which they pass. That such works, in unprofitable districts, can only be undertaken by the State, and are of doubtful expediency in the interests of the nation at large.

14. That the lower portions of rivers with convenient access to the sea, large rivers through flat countries easily made navigable far inland for large vessels, and special waterways between coal or mineral districts and large towns, have a very important traffic and provide most useful and efficient outlets for trade, and their improvement is a national benefit.

London, june, 1st, 1889.

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BARRAGES MO

BARRAGES À FERMETTES, HAUSSE

FIG. 1

BARRAGE DE MARTOT (MARTOT WEIR)
SEINE.

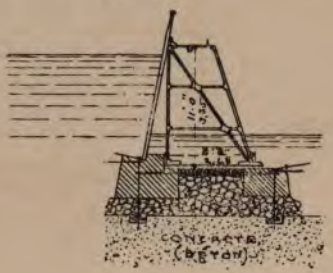


FIG. 2

BARRAGE DE SURESNES (SURESNES WEIR)
SEINE

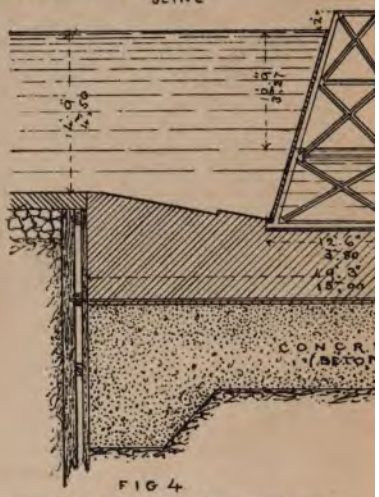
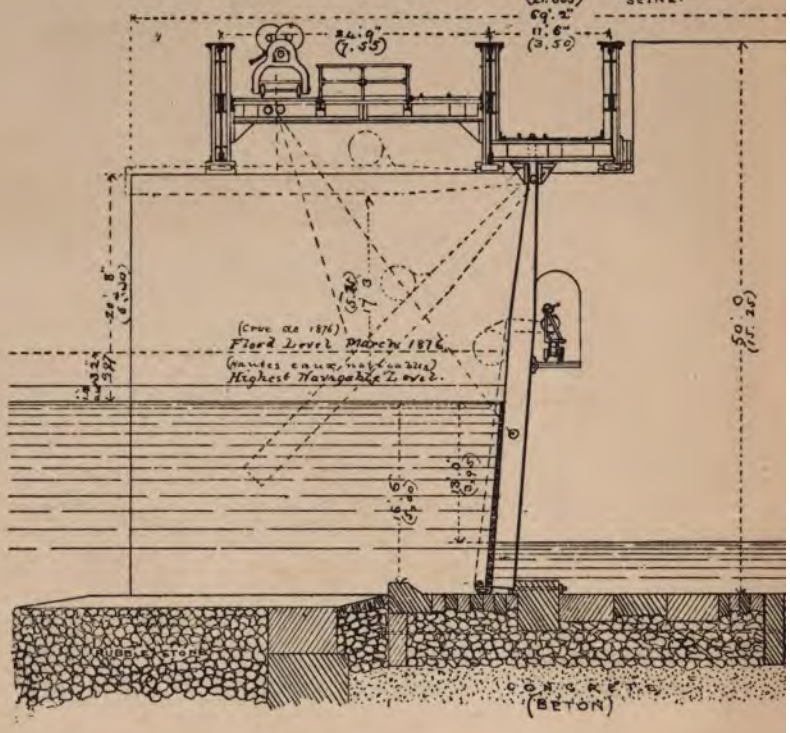


FIG 4

BARRAGE DE POSES. (POSES WEIR.)
SEINE.



ES. (MOVABLE WEIRS)

ILES, ET TAMBOUR. (FRAME, SHUTTER AND DRUM WEIRS)

FIG 3

BARRAGE DE PORT VILLEZ. (PORT VILLEZ WEIR)
SEINE

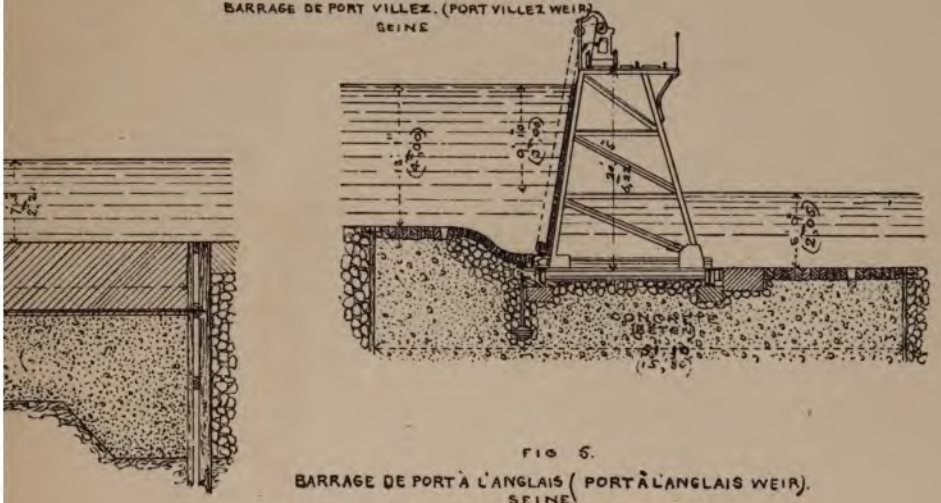


FIG 5.

BARRAGE DE PORT À L'ANGLAIS (PORT À L'ANGLAIS WEIR).
SEINE.

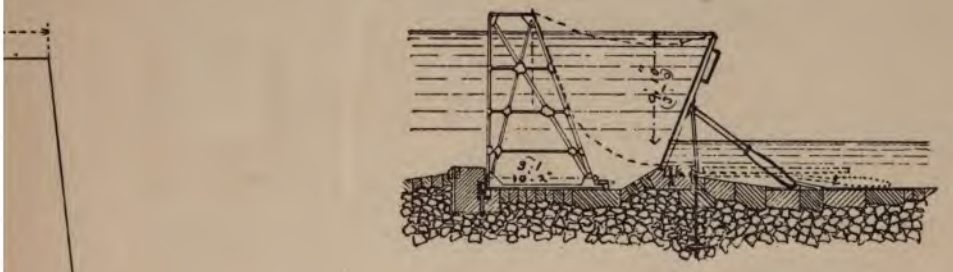
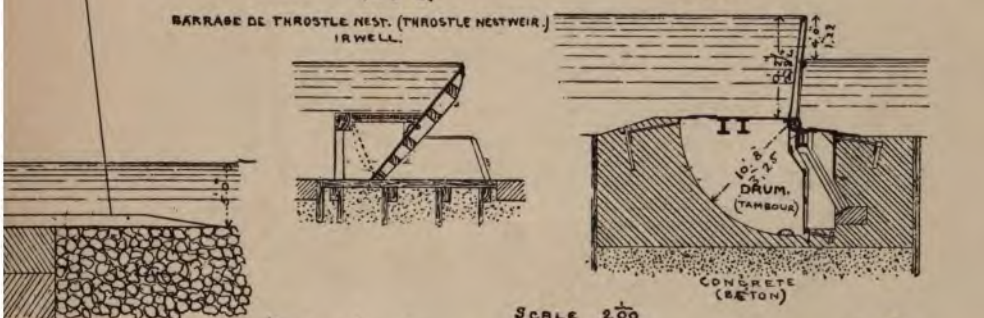


FIG 7

BARRAGE DE CHARLOTTENBURG (CHARLOTTENBURG WEIR).
SPREE.

FIG 6.

BARRAGE DE THROSTLE NEST. (THROSTLE NEST WEIR.)
IRWELL.



SCALE 1/200

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